Amendments to the Specification:

IN THE SPECIFICATION:

Please amend the following paragraphs, as shown:

Page 1, line 8

The manufacturing of advanced integrated circuits (ICs) in the microelectronic industry is accomplished through numerous and repetitive steps of deposition, patterning and etching of thin films on the surface of a silicon wafer. An extremely complex, monolithic and three-dimensional structure with complex topography of variety of thin film materials such as semiconductors, insulators and metals is generated in a typical IC fabrication process. The present trend in the ICs, which is going to continue in the foreseeable future, is to increase the wafer size and decrease the critical device dimensions. As an example, the silicon wafer size has progressed in recent years from 150 mm to 200 mm and now to 300 mm and the next wafer size of 400 mm is on the horizon. Simultaneously, the critical device dimension has decreased from 0.35 micron to 0.25 micron to 0.18 micron. Research and development for the future device dimension devices at 0.13 and next to 0.10-micron technologies is being conducted by several leading IC manufacturers. Such steps are necessary to increase the device speed, sophistication, capability and yield. These trends in the IC production technology have placed extremely stringent and divergent demands on the performance of semiconductor manufacturing equipment that deposit, pattern or etch progressively smaller device structures on the surface of a silicon wafer. This in turn translates into extremely precise control of the critical process parameters such as film thickness, morphology, and conformal step coverage over complex topography and uniformity over an increasingly large area wafer surface.

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FIG. 1 is a schematic of a conventional ALD process cycle with two inert gas pulses and two reactive gas pulses. First a reactive gas (A) is pulsed over the wafer 10. The gas molecules saturate the wafer 10 surface by chemically reacting with it to conform to the contours of the surface. This process is called chemisorption. Next an inert gas (P) pulse is sent over the surface that sweeps away excess number of gas molecules that are loosely attached (physiosorbed) to the surface and thus a monolayer of highly reactive species is formed on the wafer 10 surface. Next the second reactive gas (B) is pulsed over the wafer 10 surface. This reacts rapidly with the monolayer of first gas already adsorbed and a desired film is formed with the elimination of the gaseous by-product. Again an inert gas pulse (P) is introduced that sweeps away by-product and an excess of the second type of reactive gas. The wafer 10 surface is thus covered by a monolayer of desired film (AB) that is as thin as a single atomic layer. The surface is left in a reactive state for the complete sequence to start over. The desired film ~~is~~ thickness is built by repeating the complete reaction sequence described above for definite number of times.

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Although in principle, the technique of ALD offers a variety advantages over the industry prevalent techniques such as CVD and PVD, it has not been commercialized so far. A currently available ALD system that is capable of depositing thin films on 50 mm x 50-mm square substrates is mostly being used for early process development. As described above, ALD is known to be a slower process than CVD or RTCVD with a rate of deposition almost 10 times as slow as the later ones. To overcome this disadvantage, an ALD batch processor system has been developed. In a batch process multiple substrates are coated simultaneously to increase the

throughput. However, compared to a single wafer processor, batch processors have a few serious disadvantages such as inadequate process control, poor repeatability within the batch and from batch to batch, backside deposition on the wafer and cross contamination to note a few. Also, both of these ALD systems are based on the principle of transverse gas flow configuration above and across the heated substrate, in which a finite amount of reactive and/or inert gas is pulsed sequentially, as shown in FIG. 2.

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In a preferred embodiment, the ALD reactor covers a wafer substrate with a gas deposition sequence comprising a first reactive gas (A), an inert gas (P), the second reactive gas (B), and the inert gas (P). In one embodiment of the ALD reactor, the wafer substrate is rotated in a horizontal plane in relation to the injection tube. In a second embodiment, the wafer substrate is stationery within the chamber and the injector tube is rotated in relation to the wafer substrate. In another embodiment, the ALD reactor includes three injection tubes mounted within the chamber in parallel, the first injection tube dispenses gas (A)~~?~~, the second injection tube dispenses gas (P)~~?~~, and the third injection tube dispenses gas B. In yet other embodiments, the at least one injection tube may be configured in a cross injector tube configuration, a radial gas injector configuration, as stacked circumferencal O-rings, or as stacked longitudinal injectors.

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FIG. 1 shows the schematic of ~~an~~ a conventional ALD process cycle with two inert gas pulses and

two reactive gas pulses.

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FIG. 2 shows ~~the~~ a known compact ALD reactor with transverse flow configuration.

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FIG. 4A shows the schematic of an ALD reactor of the present invention with three fixed gas injector tubes and a rotating susceptor.

Page 9, line 21

This ~~pressing~~ present invention provides atomic layer deposition (ALD) apparatus configurations that can achieve complete wafer substrate coverage by reactive gases in a shortest path length with flow stability and in a compact volume. A combination of relative motion of the substrate with one of the various gas injection schemes in the form of projecting gas jets achieves complete surface coverage without gas depletion.

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FIG. 4A shows a schematic of an ALD reactor 13 comprising a substantially cylindrical chamber 15 having a substrate processing region with three fixed gas injector tubes 14 and a rotating susceptor 16 for holing a wafer substrate 22. According to a preferred embodiment of the present invention, A and B are reactive gas supplies and P is an inert gas supply, which are provided by mass flow controllers 18. Gas jets emanating from slots in three fixed tubes 14A, 14B, and 14C impinge directly on the diagonal of a wafer substrate 22. A pulse-rotation syncrhonization mechanism 24 ensures that the rotating susceptor 16 rotates the substrate 22 in a horizontal plane around its vertical axis at a constant angular velocity in a synchronized fashion

with the gas pulses, which are controlled by pneumatic ~~values~~ valves 20. Synchronization may not be entirely necessary as long as the wafer completes at least ½ rotation during the pulse width of the gases A, B and P.

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In another embodiment of the present invention, the top portion of an ALD reactor can be further modified to deposit atomic layers of non-stoichiometric materials such as SixGe1-x, or AlxGa(1-x)As. Fabrication of such materials ~~many~~ may require as many as four different reactants. These reactants can be categorized in to two sub-groups of reactants that are highly reactive towards each other. For example, one such group of reactants is hydrides and another one is halides of elements such as germanium and silicon. The top of the ALD reactor as described in FIG. 7 can be modified to accommodate the varied number and types of reactants and an inert gas purge as shown in FIG. 8. FIG. 8 shows the top view of an alternative configuration of an ALD reactor with multiple gas inlets for fabrication of atomic layers of non-stoichiometric materials. The penumatic valves 50 are placed in a bank of three together. The pneumatic block 50 has a common outlet that opens into the injector tubes 14A and 14B. A, B, C and D constitute reactants whereas P is an inert gas purge. The part of the ALD reactor, as shown in FIG. 4A, below the line X-X' reamins unchanged. As a variation of this configuration, the inert gas P can be mixed with the respective reactants upstream as shown by the dashed line.